2nd Microgrids: Military and Commercial

Networked Local Power Distribution With Nanogrids

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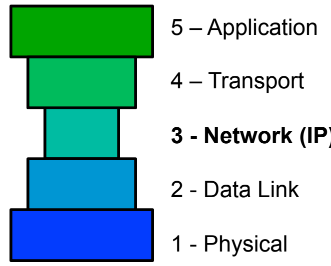
What is OSI Model equivalent for energy ?



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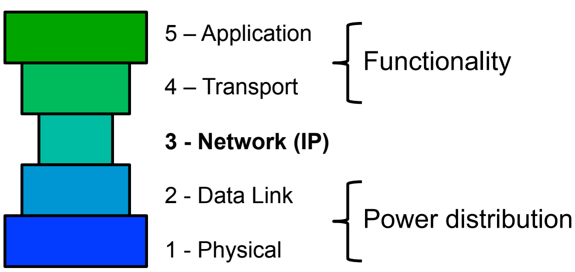

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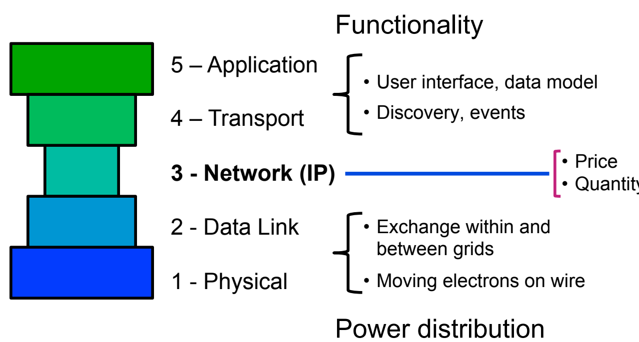

Power distribution

"Technology / infrastructure that
moves electrons from devices
where they are available
to devices where they are wanted"

- Important similarities between moving bits and moving electrons
- Important differences between moving bits and moving electrons

All bits/packets different; all electrons same

Needed system requirements (from JFQ*)

- Scalable
- Resilient
- Flexible / *Ad hoc*
- Interoperable
- Renewable-friendly
- Cost-effective
- Customizable
- Enable new features
- Enable new applications

- Any military context
- Any non-military context

**Roege, Paul* Scalable Energy Networks, *Joint Forces Quarterly, #62, Q3, 2011*

Needed system capabilities

- Scalable
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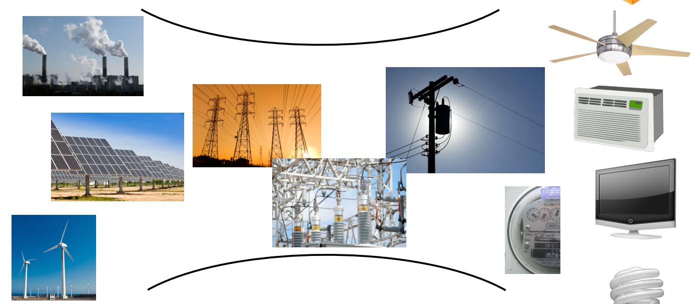
*Roege, Paul, Scal

- **Optimally match supply and demand** (price)
- Match reliability and quality to device needs
- Enable arbitrary and dynamic connections
  - devices, generation, storage, and "grids"
  - "plug and play"; networked
- Efficiently integrate local renewables and storage
- Work with or without "the grid"
  - (or any other grid)
- Use standard technology

What grid model enables this?

Traditional power distribution

- Grid is a single undifferentiated "pool" of power

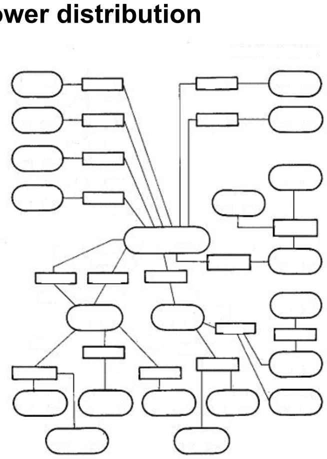


- Enormous complexity suggests difficult to manage
  - Only works because it is NOT managed

Fails to meet specified needs

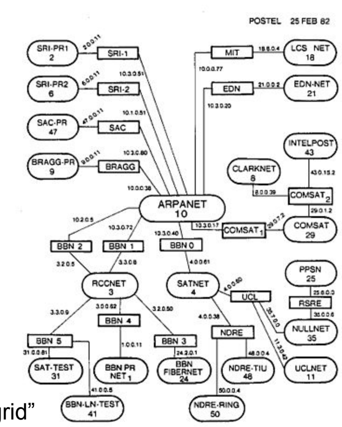
"Distributed" power distribution

- Network of "grids" of various sizes
- Grids are managed locally
- Generation and storage can be placed anywhere
- Interfaces between grids
  - enable isolation
  - enable exchanging power any time mutually beneficial



"Distributed" power distribution

- Distributed power looks a lot like the Internet
  - A network of grids ("intergrid")
- Peering exchanges can be multiple, dynamic
- With reliability at edge, core can be *less* reliable



- Smallest piece is "nanogrid"

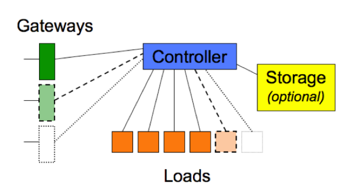
Scaling structure: communications and power

Internet	**"The Grid"**	***Wide area***
Building/Campus Network	**Microgrid**	***Management***
Local Area Network	**Nanogrid**	***Device***

What is a Nanogrid?

"A (very) small electricity domain"

- Like a microgrid, only (much) smaller
- Has a single physical layer (voltage; usually DC)
- Is a single administrative, reliability, quality, and price domain
- Can interoperate with other (nano, micro) grids and generation through gateways



- Wide range in technology, capability, capacity

Existing nanogrid technologies

No communications

- Vehicles – 12 V, 42 V, 400 V, …
- eMerge – 24 V, 380 V
- Downstream of UPS – 115 VAC

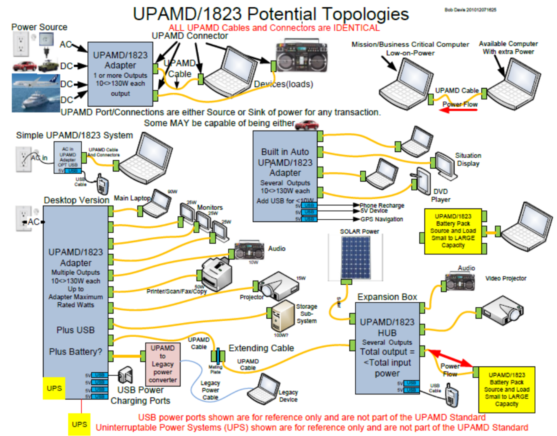
With communications

- Universal Serial Bus, USB – 5 V
- Power over Ethernet, PoE – 48 V
- HDBaseT – 48 V
- Proprietary systems

Power adapter systems (emerging)

- Wireless power technologies
- Universal Power Adapter for Mobile Devices, UPAMD – IEEE

IEEE – Universal Power Adapter for Mobile Devices



Source: IEEE

Nanogrids do NOT (but Microgrids do)

- incorporate generation
- optimize multiple-output energy systems
  - e.g. combined heat and power, CHP
- provide a variety of voltages (both AC and DC)
- provide a variety of quality and reliability options.
- connect to the grid
- require professional design / installation
- entail large costs

Village example

- Start with single house – car battery recharged every few days
  - Light, phone charger, TV, …
  - Add local generation – PV, wind, …

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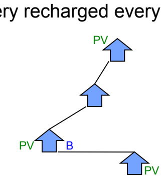

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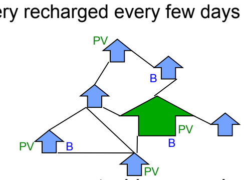
- School gets PV
  - More variable demand
- Eventually all houses, businesses connected in a mesh
  - Can consider when topology should be changed
- Existence of generation, storage, households, and connections all dynamic



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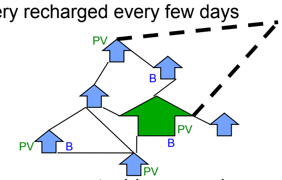
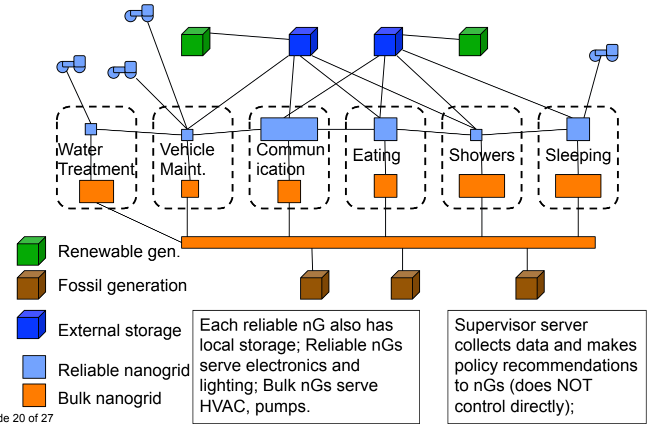
- Existence of generation, storage, households, and connections all dynamic
- Can later add grid connection(s)



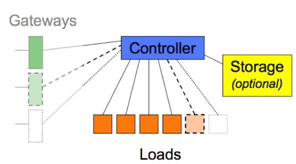
From **no electricity** to **distributed power** – skip traditional grid;
Similar to **no phone** to **mobile phone** – skip landline system

Forward Operating Base Example



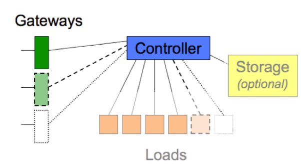
Nanogrid operation - internal

- Loads (devices) may always get 'trickle power' to communicate
- Loads request authority to use power (controller grants)
- Controller sets local price (forecast) and distributes
- Controller manages storage
- Normal operation – all allocation done by loads themselves based on price
- Emergency – controller can revoke/cut power
- Details technology-specific



Nanogrid operation – external (gateways)

- Controllers discover other grids (and generation)
- Exchange interest in sharing power (price, quantity)
- When mutually beneficial, power is exchanged
- External prices will often affect internal ones
- Controllers *may* track cumulative energy, $$$$
- *Only* data exchanged are price, quantity
- Visibility only to immediately adjacent grids



Implementation

- Initial deployment of nanogrids connected to non-communicating power sources (grid or microgrid)
- Nanogrids can be networked to each other
- Larger installations will want one (or more) microgrids
  - Nanogrids networked to communicating microgrids
- Most (sometimes all) coordination between grids via price
- In emergencies, power links can be simply dropped
- Nanogrids do not connect directly to utility grid so microgrid islanding invisible to nanogrids
- Microgrids will need to implement standard gateways (once developed)

Why Nanogrids?

- Bring individual devices into grid context
- Pave way for Microgrids
  - Increase microgrid utility; enable local microgrid prices
  - Reduce microgrid cost and complexity
  - Can scale/deploy much faster than microgrids
- Enable "Direct DC" (~10% savings)
- Better integrate with mobile devices, mobile buildings
- Help bring good electricity services to developing countries
- More secure
  - Coordinate only with immediately adjacent (directly attached) grids / devices
  - No multi-hop "routing" of power

The way forward

Research

- Better document **existing** nanogrids
  - Technologies, capabilities, applications, deployment, …
- **Create working nanogrids** – loads, controllers, gateways
- Create a nanogrid simulator

Standards development

- Define a "meta-architecture" for controllers, gateways, prices, …
- Define specific gateways (voltage, communication)
- Define nanogrid implementation for existing technologies

Deployment

- Install hardware

Conclusions

- Nanogrids can optimally match supply and demand
  - Price: internally and externally
- Nanogrids can be key to success of microgrids
  - Can be deployed faster, cheaper
- Need to be standards-based, universal
- Key missing technologies: pricing and gateways

- Nanogrids are a "generally useful technology"
  - Like Internet

Thank you